PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Measurement of Large-Scale Gene Flow: A Pathway to Understanding Adaptation and the Genetics of Climatic Tolerance

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Contractor: University of Notre Dame
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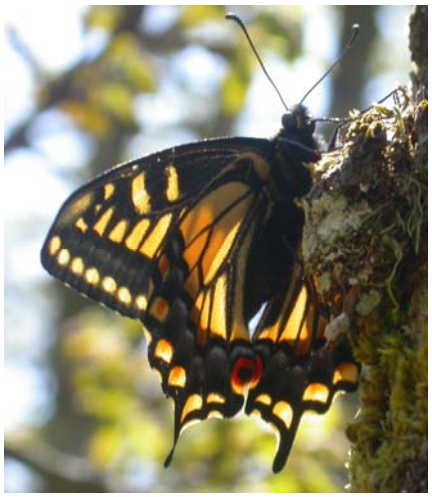
The Issue

Greenhouse gas emissions—from fossil-fueled power plants, among other sources—are altering climatic conditions in California. The state's mean climate is expected to warm 3°–5°C (5.4°–9°F) by 2100, with associated changes in precipitation and possible increases in the frequency of extreme weather events.[1] The resulting effects on California's biological resources may range from minor to devastating, depending how well various species adapt to the changing conditions. To properly manage California's unique biological resources in the face of climatic change, scientists need to understand the underlying drivers of ecological responses to climate change.



Comparing the genetic diversity of Anise Swallowtail (*Papilio zelicaon*) populations to populations of another species will yield fundamental insight into the gene flow dynamics that drive ecological response to climate change.

Project Description

This research project tests critical assumptions about the genetic differences between populations in California, differences that may determine the ecological responses of species to a changing climate. The project uses two flagship butterflies that inhabit two of California's most prized ecosystems—oak savanna and native grassland—to study if species with differing characteristics have differing potential for adaptation to local conditions. Determining the possibility and extent of such adaptation is critical to understanding the large-scale responses of organisms to climate change—specifically, the changing boundaries of species' distributions.

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[1] Hayhoe, K., et al. 2004. Emissions pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences* 101: 12422–12427.

The movement, or flow, of genetic information is an essential determinant of species adaptation to local conditions, including climate. Most ecologists assume that climate change, as caused by the emission of greenhouse gases, will cause species to shift their geographic distributions poleward. However, local adaptation and genetic differentiation due to restricted gene flow among populations can change this picture considerably: if populations throughout a range are adapted to the climate that occurs in their local habitats, widespread population declines could result under climate change.

This project investigates local adaptation and the movement of genes among populations by measuring differences in the genetic sequence of individuals from different locales. Such differences are a precursor to genetically determined differences in climatic tolerance. The project examines such differences in two butterfly species. The Propertius Duskywing (*Erynnis propertius*) and the Anise Swallowtail (*Papilio zelicaon*) capture a large difference in body size and resource specialization. These characteristics are likely to be important determinants of interpopulation movement and thus the amount of genetic difference that accumulates among populations.

Considering the differences in body size and resource use of the two butterfly species, the project team predicts that the smaller and more specialized *E. propertius* has a greater degree of genetic differentiation than does *P. zelicaon*. The project team also predicts increased isolation of *E. propertius* populations the further southward (i.e., closer to the range boundary) one proceeds. If these predictions are supported, species like *E. propertius* might decline under climate change in California. In contrast, the team predicts that larger and less specialized species like P. zelicaon will show little differentiation and may shift their range without widespread declines. If a large amount of genetic differentiation is seen in both species, the argument for considering widespread population declines under climate change may be applicable regardless of a species' dispersal capacity and specialization. If differentiation is not observed in both species, range shifts without declines may occur even in small and specialized species.

To assess the extent of genetic differences among populations, the study will measure the sequence similarity and the number of alleles (genetic forms) at various sites throughout California. Specimens of both species will be sought wherever host plants co-occur with nectar resources. Collected specimens will be returned to the Hellmann Laboratory at the University of Notre Dame for assessment of genetic diversity using mitochondrial genes (mtDNA) and microsatellites. Preliminary exploration with mtDNA sequence variation and microsatellite markers in these species suggests that high versus low rates of genetic exchange between populations can be distinguished and that specific geographic regions can be identified and mapped as more genetically distinct than other locales.

It is anticipated that future research will follow from this work. For example, locales identified in this project as highly divergent can be tested against other populations to determine if genetic differences capture differences in climatic tolerance. To enable such functional studies, however, researchers must have an initial understanding of genetic variation and genetic exchange across space for species that that are hypothesized to differ under climate change.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Develop cost-effective approaches to evaluating and resolving environmental effects of energy production.** Climate change from fossil fuel combustion has been identified as a major threat to the natural systems on which the state depends. This study examines if and why species respond differently to climate change based on their ecological characteristics, thereby providing fundamental insight into the impacts of climate change on California's bioresources. As such, the project provides a basis for identifying and protecting species threatened by climate change.
- **Provide environmentally sound energy.** The findings of this study can be used to further assess the risks of fossil fuel emissions to the state's natural resources. Based on those risks, Californians can better understand the need for a more environmentally sound energy system.

Final Report

The final report on the results of this work will be available in the fall of 2007.

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